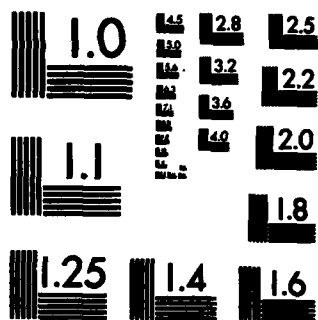


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EYELID MOTION SEQUENCES  
PREDICTIVE OF DECISION ERRORS

by

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Final Report of grant AFOSR-83-0129 Transcription and Analysis of Sequential  
Eye Movement Data.

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In the final report of the Summer Faculty Research Program for 1982 a tentative conclusion was advanced that the loss of attention was progressive over time-on-task and associated with at least five substages of attention which can be identified by sequences of oculomotor events. A follow-on grant was awarded for the purpose of transcribing additional data using the Sony BVU 800 so as to advance our knowledge of the relationships between oculomotor sequences and levels of attention. The most current state of knowledge at that time was provided by the Behavioral Research Laboratories of Washington University (Stern et al 1980) who advanced the hypothesis that attention errors were associated with long eye lid closing durations and long durations closures. The 1982 Summer Faculty Research report offered the tentative conclusion that the attention errors were associated not merely with long closure durations, but more specifically with the slow eye movements (SEM's) and precursors of SEM's that occur during the long lid closures. Thus a growing body of information supports the hypothesis that a complete failure of attention i.e. the missed signal, can be predicted by oculomotor patterns. But if as has been suggested a continuum of attention exist from an alert state to a failure to detect a stimulus, then there must exist some lowered level of alertness at which attention is intact but decision errors occur. The purpose of the follow-on effort being reported here was to explore the sequences of oculomotor events during decision errors and determine if predictions were possible.

The task consisted of a variation of the serial probe recognition procedure and the data came from control observations collected during a drug evaluation research project at the School of Aerospace Medicine during the summer of 1983. The task consisted of three, one second nonsense syllables

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presented at one second interstimulus intervals. These auditory stimuli were followed within four seconds of a probe stimulus which was either the same as one of the three preceding stimuli or different from all three. The nine subjects were instructed to press a dead man key upon hearing the first stimulus and hold it down until hearing the probe stimulus where upon they were to release the dead man key and press a "same" or "different" response key. Thus it was possible to separate attention errors from decision errors in which the subject attends to all stimuli but fails to correctly identify the probe as a same or different stimulus. For analysis purposes each error trial was matched for transcription with the most temporarily contiguous correct trial. During the presentation of this task this subject's eyes were video taped and the data transcribed on a 16.7 ms basis. Three channels of simultaneous videotape and electro-oculographic data were transcribed on each subject: stimulus/response events, vertical eyelid and eye movement events, and horizontal eye movement events. The same coding scheme used in preliminary report was used here. The subjects were instructed to stay up late the night before the early morning data collection and were put through a progressive relaxation, drowsiness induction procedure before collecting data. Once relaxed the subjects were run on the serial probe recognition task until they showed evidence of drowsiness such as SEM's or downward shifts in the gaze angle at which time approximately 30 minutes of continuous data were collected. Thus the subjects were in a low fatigue, high drowsy condition.

The analysis of video and EOG data allowed for an identification of five events in the sequence of eyelid movements: (1) lid up (LU) in which the lid is up and static, (2) lid above pupil (LAP) in which the lid is in motion above the pupil (3) lid over pupil (LOP) in which the lid is in



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motion over the pupil, (4) lid below pupil (LBP) in which the lid is in motion below the pupil, and (5) lid down (LD) in which the lid is down and closed. In addition measurements were taken of the gaze angle to determine when the gaze angle was perpendicular as is normal in an alert subject and when it was below perpendicular as occurs as a function of time-on-task. The significance of the gaze angle shift is that it may be indicative of a lowered state of alertness which is not measured by EOG alone. In summary nine drowsy but not fatigued subjects were measured for eyelid sequence during performance on an auditory SPR task in which attention errors were separated from decision error. An initial data analysis indicated 46 decision error trials and each was transcribed and matched to the 46 most temporarily adjacent correct trials which were also transcribed. On eight occasions the subjects failed to detect the probe stimulus and these eight trials were coded as attention errors and transcribed. On eight occasions the subjects failed to detect the probe stimulus and these eight trials were coded as attention errors and transcribed. Thus the subjects appeared to be sufficiently drowsy to make decision errors but alert enough to detect stimuli.

A sequential analysis of the data indicated two types of blink episodes, each subdivided into closing and reopening sequences. The Type I closing sequence consist of five elements, LU  $\longrightarrow$  LAP  $\longrightarrow$  LOP  $\longrightarrow$  LBP  $\longrightarrow$  LD (see table 1) and is associated with a perpendicular gaze angle. The Type II closing sequence which occurs late in time-on-task consists of three elements, LU  $\longrightarrow$  LOP  $\longrightarrow$  LD (see table 2) and is associated with a gaze angle below perpendicular. In the Type II closing sequence the gaze angle is so low that the entire lid movement is restricted to the field of the pupil. On correct trials the duration of the LOP component in a Type I closing sequence ( $\bar{X}=65.8$  ms) is shorter than the Type II closing sequence LOP component ( $\bar{X}=105.1$  ms) and the

difference is statistically significant ( $t=4.214$ ,  $sf$  (pooled)=170,  $\alpha=.05$ ). The same relationship exist for LOP duration comparisons on decision error trials ( $\bar{X}=117.9$  versus 144.0): but the difference was not statistically significant. The relative density of Type I blinks is greater on correct than decision error trials:

	Type I Blink	Type II Blink
Correct trial	42%	46%
Decision Error Trial	37%	48%

Thus decision error trials are associated with lower a density of Type I blinks and higher density of Type II blinks, and the duration of the LOP component of the closing sequence is longer on Type II blinks.

The duration of the LOP component of both Type I and Type II closing sequences importantly descriminate between correct and decision error trials. The Type I sequence LOP mean duration on a correct trial is 65.8 ms versus 117.9 ms on a decision error trial and the difference is significant ( $t=1.898$ ,  $df$  (pooled)=175,  $\alpha=.05$ ). On the Type II closing sequence the LOP duration was shorter on correct ( $\bar{X}=106.1$  ms) than decision error trials ( $\bar{X}=144.0$  ms) but the difference was not significant. LOP durations on attention error trials were longer than on correct trials for both Type I ( $\bar{X}=186.7$  ms versus 65.8 ms) and Type II ( $\bar{X}=127.1$  ms versus 105.1 ms) sequences: statistical inferences not being drawn because of the relatively small sample size of attention errors. Thus LOP durations on Type I closing sequences discriminate between correct and decision error trials at alertness levels above that seen with attention errors. Type II closing sequences had a simular pattern but the difference was not statistically significant.

The relationships between correct and error trial LOP durations on reopening sequences is opposite that on closing sequences. The reopening

LOP durations are longer on correct ( $\bar{X}=235.9$  ms) than decision error trials ( $\bar{X}=205.8$ ) but the difference is not significant on Type I sequences. On Type II sequences the correct trial LOP mean duration was 234.7 ms versus 190.4 ms on the decision error trials and the difference was significant ( $t=2.885$ ,  $df$  (pooled)=265,  $p<.05$ ). Thus for correct trials the LOP velocity is faster on closing and slower on reopening than an error trials.

The Type I reopening sequence consists of five elements:

LD  $\longrightarrow$  LBP  $\longrightarrow$  LOP  $\longrightarrow$  LAP  $\longrightarrow$  LU

while the Type II reopening sequence consists of three elements:

LD  $\longrightarrow$  LOP  $\longrightarrow$  LU: both initiated from the lid down position.

Stern et al (1980) reported the lid closure duration to be longer on attention error trials than on attention correct trials. In the present effort the lid down duration was greater on decision error trials. (Type I  $\bar{X}=222.5$ ) than on correct trials (Type I  $\bar{X}=65.9$ ) and the difference was statistically significant ( $t=1.627$ ,  $df$  (pooled)=159,  $p<.05$ ). The Type II lid down durations were not statistically significant. Thus the present finding extend the Stern et al (1980) findings to decision errors.

The relative density of eyelid closures differed across types of blinks and trials. The following table shows mean values of inter blinks intervals across types of blinks and trials:

	Type I	Type II
Correct Decision	924 ms	1251.9 ms
Decision Error	905.6 ms	1002.4 ms

On correct trials the density of Type I sequences is significantly greater



than Type II sequences  $t=2.085$ ,  $df$  (pooled)=179,  $p=.05$ ). Other comparisons were not significant. Thus Type I sequences are more prevalent on correct than decision trials.

The fundamental hypothesis advanced in this report is that the Type I sequence represents a higher state of alertness than the Type II sequence. The data in support of this position are (1) that the Type II sequence increases with time-on-task and (2) that correct decisions are associated with higher densities of Type I blinks. The essential difference between the types of blinks is that Type I includes LAP and LBP lid motion components while Type II does not. However, the LBP and LAP components do not discriminate between correct and decision error trials, and only the LOP motion component has any predictive significance.

It may be possible to view alertness, and the implied capacity to process information, as existing on a continuum. Although these altered states of alertness exhibit subtle variations, we now have at least three points documented that correlate eye movements to altered states. The Shimanono et al (1965) report describes the highest state yet described. This work may be interpreted to indicate that the highest known state, a near manic condition, the density of saccades is significantly greater than slow eye movements and that in normals saccades are fewer and slow eye movements more frequent. At the other end of the alertness continuum Stern et al (1980) have shown that the missed signal is a failure of attention that can be predicted by long duration lid closures and slow closing velocities. The present report describes an attention level in between these two, a level at which subjects are attending but making decision errors which can be predicted by LOP velocities. Presumably numerous other levels of alertness exist which may be predicted by other oculomotor properties.

TABLE 1

## CLOSING SEQUENCE TYPE I

LU  $\frac{91/324}{924.0/788.8}$  → LAP  $\frac{96/206}{60.3/57.3}$  → LOP  $\frac{90/463}{65.8/42.9}$  → LBP  $\frac{81/209}{54.8/70.6}$  → LD

## DECISION ERROR

LU  $\frac{60/291}{905.6/869.4}$  → LAP  $\frac{68/143}{64.8/58.9}$  → LOP  $\frac{87/425}{117.9/256.7}$  → LBP  $\frac{76/197}{91.2/199.3}$  → LD

## ATTENTION ERROR

LU  $\frac{11/45}{1263.4/1244.8}$  → LAP  $\frac{12/25}{34.7/13.2}$  → LOP  $\frac{24/83}{186.7/571.8}$  → LBP  $\frac{22/50}{86.2/149.1}$  → LD

\*These tables can be reas according to the following example:

LU  $\frac{91/324}{924.0/788.8}$  LAP

The lid above pupil component occurred on 324 occasions and on 91 of those was preceded by the lid up position at a mean duration of 924.0 ms and a standard deviation of 788.8 ms.

TABLE 2

## CLOSING SEQUENCE TYPE II

## CORRECT SPR RESPONSE

LU  $\frac{88/324}{1251.9/1258.0}$  → LOP  $\frac{82/463}{105.1/75.6}$  → LD

## DECISION ERROR

LU  $\frac{100/291}{1002.4/917.8}$  → LOP  $\frac{67/425}{144.0/267.3}$  → LD

## ATTENTION ERROR

LU  $\frac{22/45}{1200.5/1490.8}$  → LOP  $\frac{14/83}{127.1/67.3}$  → LD

TABLE 3

## OPENING SEQUENCE TYPE I

## CORRECT SPR RESPONSE



## DECISION ERROR



## ATTENTION ERROR

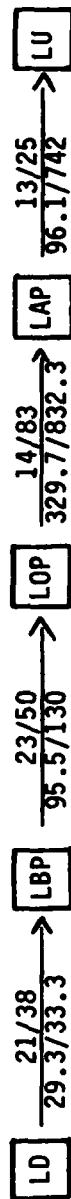


TABLE 4  
OPENING SEQUENCE TYPE II

CORRECT SPR RESPONSE



DECISION ERROR



ATTENTION ERROR



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